Back-tracking drifting seaweeds in East China Sea with OFES currents forcing

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ABSTRACT

Drifting seaweeds plays a major role in areas where they are present. We describe a computer model that clarifies the roles of those seaweeds in relation to their transport using a particle back-tracking algorithm. Ocean currents data from the OFES model (OGCM for the Earth Simulator) is used to force trajectories backwards to find where particles may come from. Behaviour of drifting seaweeds of the Sargassum family has been implemented in the model, and experimented in East China Sea to verify a seaweed collection campaign in May 2002.

1 Introduction

Drifting seaweeds plays a major role in areas where they are present. They act as nursery for a vast amount of species, but also are a good bio-indicator of water quality. Such algae hosts moving ecosystems, and identifying the drift path is necessary in order to clarify their roles. Particle tracking techniques have proven to be the most robust and common approach to identify drifting paths [Reynolds(2003)]. Trajectory and spreading models usually uses resolutions of Lagrange particle tracking technique [Garcia-Martinez and Flores-Tovar(1999)], where particles simulate material transported by the water current, with various spreading mechanisms. The most common application of particle tracking spread models is the simulation of oil spills. Nevertheless some works [Garcia-Martinez and Flores-Tovar(1999)] shows that the common Euler approach used to solve Lagrange equations is very sensible to time stepping and might induce numerical errors that causes erroneous drift and exaggerate the spread. This work introduces a discrete event approach that is more suited to the simulation of ecological systems in highly non uniform flows.

The application presented in this report is the analysis and simulation of Sargassum Sea grass distribution in East China Sea to clarify ecological roles of this specie.

Recently a lot of drifting seaweeds were found in the East China Sea surrounded by Taiwan, China and Japan in spring. The Kuroshio Current passes north-easterly along the surface layer above 200 m isobaths in the East China Sea. Tsushima Current is bifurcated southwest of Kyushu Island from the Kuroshio Current and enters the Japan Sea through Tsushima Straight. Origin of Sargassum species newly found as drifting seaweeds are thought to be geographically limited around Chinese coast in the East China Sea. Sargassum species were collected during on-site studies near Chinese coasts in East China Sea and Yellow Sea, and the zone further delimited with satellite imagery. Nevertheless, it is important to verify those assumptions with the use of simulation software to identify particle paths, distribution and the timing of the distribution.

2 The Sargassum algae model

A patch of algae is treated as a particle that has a specific location, area and biomass. The model calculates trajectories based on the assumption that behaviour of drifting Seaweeds, like oils pills, can be idealized by a large number of particles that moves in three dimensions in a water body by advection and spreading dynamics. To determine the advective velocity field, the simulation uses data from the OFES model [Masumoto et al (2004)] that simulates ocean current, surface elevation, temperature, salinity with very high resolution. The velocities resulting from the hydrodynamic model is later used by the spread model to compute trajectories. Nevertheless, in highly non uniform flows, such as found in oceans, this method stills require a relative small time step to keep a good accuracy in zones of high speed currents.

One way to overcome this limitation is the use of discrete event simulation, where there is no fixed time step, and the calculation is made instead for a size step Δq. A time advance estimate ta is computed to be the time taken by the particle to travel the distance Δq. After each iterations, local time at the particle is updated to be tnext = t+ta. An active particle generates an event at that time that is stored in a giant event queue. The queue is then sorted by time, and events are popped to move particles. Each time a particle moves, it re-generates an event, unless the particle is dead or not moving anymore.

Backtracking simulation is done by assigning a negative value for Δq. Instead of going forward, the particle is then moving backwards in the currents and forcing data is loaded in reverse time. Every time a particle moves, it spawns in random directions that are relative to the current flow. The overall area covered by the particle is the backtracking area representing all possible origins of the particles. Random velocities V are obtained by random sampling in the range of velocities [-Ur, Ur], [-Vr, Vr] [-Wr, Wr] to simulate spreading of seaweed patches. Those ranges are assumed to be proportional to diffusion coefficients in x, y and z. Velocities diffusion has been estimated from a study from [Bograd et al.(1999)], which uses satellites tracking of drifters in the northern Pacific to perform empirical estimates of diffusion coefficients. The relative diffusion coefficient is expressed by the following Formula: Du = Ur/U(rms) and Dv = Vr/V(rms). [Bograd et al.(1999)] found an average Du to be 0.1 and Dv = 0.08. In the model, Dw = Wr/W(rms) is given by the mortality and loss of floatability of the seaweed. Therefore, it is not assumed to have additional random motion, because the mortality distribution in itself is random.

This extensive survey also suggests that the use of that overall diffusion coefficient is a sufficient approximation for modelling studies. The general equation for Euler with dispersion is Vd = (Vx + Vd)/ dt. To estimate Vd, we then apply the diffusion coefficient to the averaged speed obtained from the flow calculation.
3 Application and results

In this section, the model is applied to predict Sargassum distribution in East China Sea. The Laboratory of Behavior, Ecology and Observation Systems at the Ocean Research Institute (University of Tokyo) filed observation in the East China Sea using R/V Hakuho-Maru. They mapped geographical distribution of drifting seaweeds and collected samples of drifting seaweeds to detect the species. Figure 1a) shows the distribution of Sargassum in the East China Sea (triangles, squares and circles) as found by the Laboratory in May 2002. Origin of Sargassum species newly found as drifting seaweeds are thought to be geographically limited around Chinese coast in the East China Sea.

Figure 1 b,c,d,e) presents the results of the backtracking simulation with a release date of 15 June which is the time Sargassum are usually seen north of Tokyo Bay, and a particle lifetime of 90 days. The numerical simulation provides results that prove to be very similar to the observation. In particular, it shows that the seaweeds are distributed on a path that is more north than the observation, which provides a good hint on where should be performed next observation.

4 Conclusion

We have introduced a new combination of techniques that proves to be well suited for the modelling of drifting ecosystems. From a marine ecology point of view, we have described where and when comes from the Sargassum algae’s arriving in Japan. This numerical experiment helps to understand the drifting ecosystem and is well validated by field observations.

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References


